# INSECT ATTACK AND TREE MORTALITY IN PARAQUAT-TREATED STANDS AT THE SAVANNAH RIVER PLANT

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Abstract.--We have collected data on bark beetle infestation and associated tree mortality from studies of lightwood induction with paraquat at the Savannah River Plant. Loblolly pine mortality following dowel treatments was excessive; 31 and 90 percent for one and two dowels per tree, respectively. On loblolly pines sprayed with 0.1 percent BHC, application of 5 percent paraquat solution to 1/3-circumference bark streaks caused no additional mortality over natural levels. Slash pine treated with a "Jim-Gem" injector and 2 percent paraquat had a sizable increase in mortality the second growing season, bringing the total volume loss after 15 months to 10 percent. In loblolly pines, the season in which a 2 or 5 percent solution of paraquat was applied to 1/3-circumference bark streak did not influence mortality, which was low for all seasons. Sprays of BHC, Dursban (chlorpyrifos) and Reldan (chlorpyrifos-methyl) were equally effective but unnecessary, because mortality increased by only 3.8 percent when no insecticide spray was applied. Beetle attack and associated tree mortality increased as the concentration of paraquat solutions increased.

Additional keywords: ~~Pinus elliottii, P. taeda,~~ black turpentine beetle, Ips spp., lightwood.

Since the discovery that application of the herbicide paraquat would induce lightwood formation in southern pines (Roberts 1973), one of the major concerns has been the subsequent increase in bark beetle infestation of treated trees noted in most paraquat research conducted in the Southeast. In some cases it has resulted in unacceptable levels of tree mortality (Ericksen 1978, Stubbs 1978). In order of insect importance, mortality losses have been caused by engraver (Ips spp.), southern pine (Dendroctonus frontalis Zimm.) and black turpentine beetles (Dendroctonus terebrans Olivier). Secondary insects, principally ambrosia beetles (Platypus spp.), attacked dying trees but seldom caused mortality.

This paper describes bark beetle activity and tree mortality after paraquat treatment in a series of studies conducted at the Savannah River Plant in South Carolina. These studies were not designed solely to observe beetle activity, but the results are pertinent. The southern pine beetle population on the Savannah River Plant is low, and black turpentine beetle attacks on paraquat-treated trees have caused negligible mortality. Ips beetles are the primary insect pests and account for most insect-caused tree mortality in this area.

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Since the objectives of the studies described and the treatments imposed differ, each study is presented separately.

## LARGE PROOF-OF-CONCEPT STUDIES

### Methods

Pine plantations, ages 22 to 23, were treated as previously described (Stubbs 1977). Briefly, a fairly contiguous block of loblolly pine (*Pinus taeda* L.), about 140 acres in size, was treated between September 1976 and January 1977. The five different treatments used were: control, 1/3-circumference bark streak and 5 percent paraquat, drill hole and 5 percent paraquat, one dowel, and two dowels (2.04 lbs. of paraquat/ft.$^3$ of dowel). All treatments except the control plots were sprayed with 0.1 percent BHC in water.

Slash pine (*Pinus elliottii* Engelm. var. *elliottii*) plantations were treated during May and June of 1977. Trees were treated with a "Jim-Gem"[2/] tree injector and 2 percent paraquat, with injections spaced on 5-inch centers. Following treatment trees were sprayed with 1 percent BHC in diesel fuel.

### Results

After 18 months, the 1/3-circumference bark streak with 5 percent paraquat caused the least mortality of those treatments tested on loblolly pine (Table 1).

Table 1.--Bark beetle attack and associated mortality of loblolly pine following four paraquat treatments

| Treatment[a/][b/] | Beetle Incidence Before Treatment | Beetle Incidence At 18 Months[c/] | Mortality At 18 Months |
|---|---|---|---|
| | - Percent of trees involved - | | |
| Control | 4.1 | 4.1a[d/] | 0.4a |
| Bark streak, 5% paraquat | 4.2 | 6.0ab | 1.5a |
| Drill hole, 5% paraquat | 5.7 | 12.4b | 6.9b |
| One dowel[e/] | 2.8 | 19.0c | 31.0c |
| Two dowels | 6.7 | (No Data) | 90.0d |

a/ 3000 trees per treatment, except two dowels which had 10,100 trees.
b/ All but control trees were sprayed with 0.1 percent BHC in water.
c/ Live trees under attack.
d/ Within columns, means followed by the same letter do not differ significantly at the .05 level.
e/ 2.04 lbs. paraquat per ft.$^3$ of dowel.

2/ Mention of trade names is solely to identify materials tested, and does not constitute endorsement by the U.S. Department of Agriculture.

Mortality after this treatment was not significantly greater than on untreated control plots. The drill hole treatment caused higher mortality than the bark streak treatment. This result is surprising, since others have reported that given equal paraquat concentrations, larger wounds result in a greater incidence of beetle attacks (Drew 1977 , Overgaard et al. 1977). Both one and two dowel treatments caused unacceptable tree mortality--31 and 90 percent, respectively.

There has been some concern that beetle populations might build up in treated trees and then attack surrounding trees, causing severe losses. This was certainly not the case in these tests. Even though all treatments were in the same area and in many cases actually bordered on each other, there was no evidence of a significant spread of beetles from the dowel treatments. Thus, as indicated by others (Clason 1978, Drew 1978, Hertel et al. 1977) it appears there is little threat of beetles causing any significant mortality in adjacent untreated, or in this case, even less severely treated trees.

On slash pine, tree mortality was low for the first 10 months after treatment (Table 2). However, during the next 5 months, which corresponds to the second growing season, mortality increased to 13.2 percent. Because mortality increased as tree size decreased, stand volume loss was less at about 10 percent. Even though this loss is fairly high, about 2 cords/acre, preliminary data indicate it will be more than offset by the value of the additional oleoresin. The profitable break-even point is not reached until volume loss amounts to about 20 percent.

Table 2.--Bark beetle attack and associated mortality of slash pine following injection with 2 percent paraquat[a/]

| Treatment Duration | Bark Beetle Incidence[b/] | Cumulative Tree Mortality |
|---|---|---|
| | - Percent of 14,200 trees involved - | |
| Pretreatment | 1.5 | —— |
| 5 months | 4.0 | 2.2 |
| 10 months | 3.1 | 3.7 |
| 15 months | 3.2 | 13.2 |

a/ After treatment all trees were sprayed with 1 percent BHC in diesel fuel.
b/ Live trees under attack at the end of each period.

## PARAQUAT TREATMENT, SEASON, AND INSECTICIDE SPRAY

### Methods

The design and treatment of this study were described in detail by Moore (1977). The treatments, which were applied to plots of 20 trees each, were: control, 1/3-circumference bark streak (wound only), 1/3-circumference bark streak with 5 percent paraquat, 1/3-circumference bark streak with 2 percent paraquat and insecticide, and 1/3-circumference bark streak with 5 percent paraquat and insecticide. These were replicated over three different insecticide sprays--BHC, Reldan (chlorpyrifos-methyl), and Dursban (chlorpyrifos) at two levels each. All treatment combinations were applied in spring, summer, and fall to loblolly pine plantations at each of three locations.

### Results

Even though season and length of treatment are confounded, season of treatment did not significantly influence tree mortality (Table 3). Also, because these data show additional mortality with longer treatment duration, average mortality should be even closer once all seasonal replications reach 28 months. Only the 5 percent paraquat treatment without insecticide had significantly higher mortality (3.8 percent) than the control. Mortality was not significantly reduced when this treatment was used with insecticide. Thus, spraying, which accounts for approximately half the treatment cost (Stubbs 1978), certainly would not pay in this case. Because use of insecticide did not affect mortality, it is not surprising that there was no difference in tree mortality by insecticide type.

## WOUND TYPE, PARAQUAT CONCENTRATION, AND PARAQUAT DOSAGE

### Methods

A factorial design was employed in this study. Wound types were 1/3-circumference bark streak and "Cran-Jector" incisions, in combination with 0.5, 2, 4, 6, and 8 percent paraquat applied at rates of 0.15, 0.40, and 0.65 ml of solution per inch of wound. An untreated control was also included giving a total of 31 different treatment combinations. Each of these was applied to 2 five-tree plots in loblolly plantations, age 22, at three locations. All trees were sprayed with 0.5 percent lindane (gamma isomer of BHC) in water after treatment.

### Results

Past tests have indicated that bark beetle attacks increase with increasing paraquat concentration (Drew 1978, Overgaard *et al.* 1977). The design of this study is particularly suited to investigation of this relationship. Three months after treatment, beetle attacks were positively correlated with paraquat concentration for both the 1/3-circumference bark streak and injector wounding methods (Figure 1). Although attacks appear to be higher with the bark streak than with the injector at 4 and 6 percent concentrations, the difference is not significant. When data from both wound types are combined the result is a smooth curve with attacks increasing at an exponential rate:

$$Y = .81\ (1.61^X),\ R^2 = .99$$

Y = Percent of trees attacked

X = Percent paraquat

Table 3.--Mortality of paraquat treated loblolly pine by season of treatment, treatment method, and insecticide

| Factor[a/] | Tree Mortality |
|---|---|
| | - Percent of trees involved - |
| Season (Treatment Duration) | |
| Spring (18 months) | 2.2a[b/] |
| Summer (28 months) | 4.4a |
| Fall (22 months) | 3.8a |
| Treatment | |
| Control | 2.0a |
| 1/3-Bark streak (wound only) | 2.2a |
| 1/3-Bark streak, paraquat 2%, insecticide | 3.1ab |
| 1/3-Bark streak, paraquat 5%, insecticide | 4.0ab |
| 1/3-Bark streak, paraquat 5%, no insecticide | 5.8b |
| Insecticide | |
| BHC | 2.8a |
| Dursban (chlorpyrifos) | 3.3a |
| Reldan (chlorpyrifos-methyl) | 4.6a |

[a/] Seasonal entries based on 1800 trees, treatments on 1080 trees, and insecticides on 720 trees.

[b/] Within a factor, means followed by the same letter do not differ significantly at the .05 level.

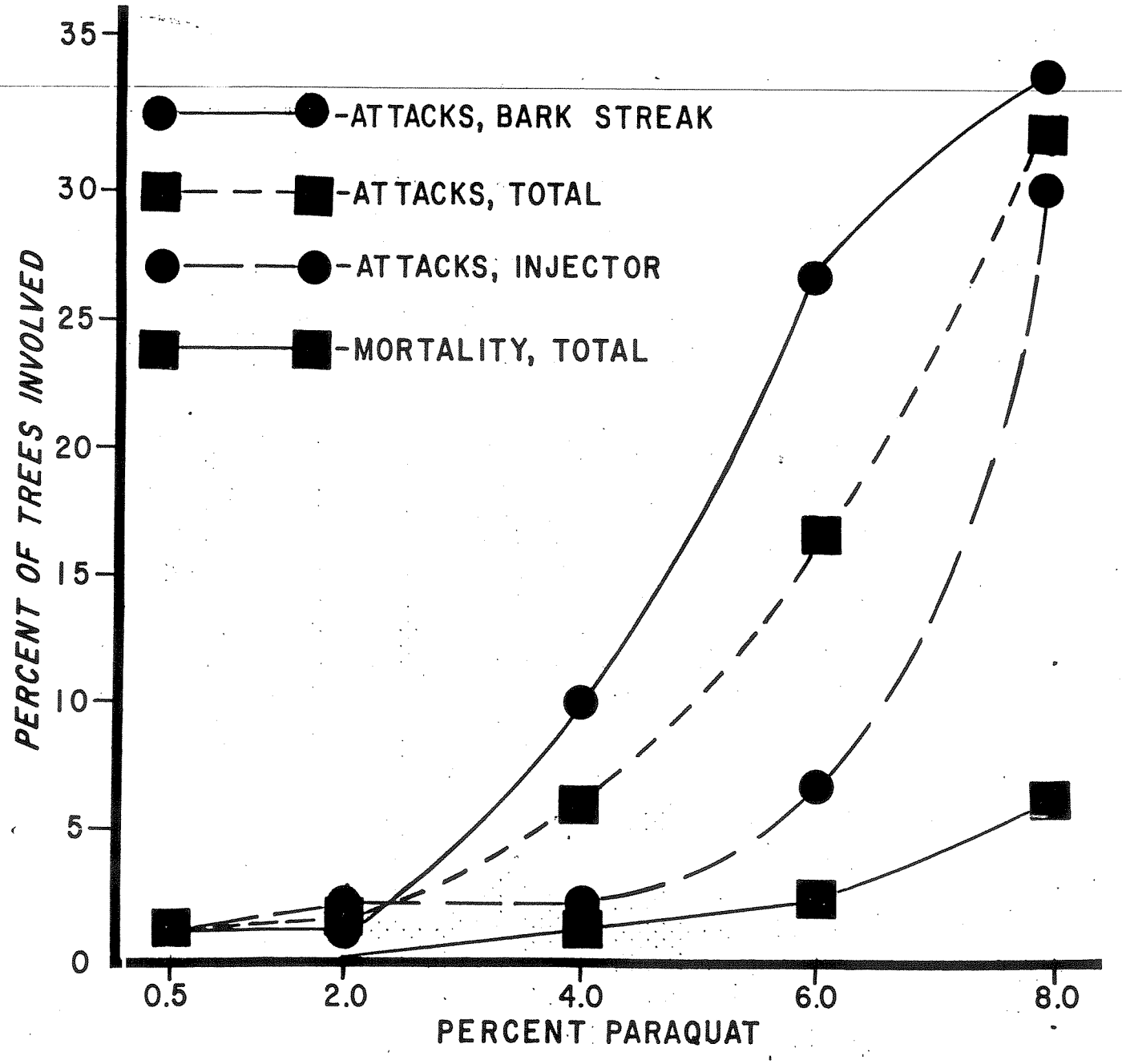


FIGURE I.--BARK BEETLE ATTACKS AND ASSOCIATED MORTALITY OF LOBLOLLY PINE BY PARAQUAT CONCENTRATION THREE MONTHS AFTER TREATMENT.

Tree mortality also has a positive relationship with concentration, but is rising at a slower rate. For this combination of wound methods, species and location, it appears that paraquat concentrations even moderately greater than 4 percent substantially increase insect problems. However, it will be necessary to wait until plots reach a more practical treatment duration, from the standpoint of sufficient oleoresin increase, before final conclusions are drawn.

The amount of paraquat solution which trees received had little effect on bark beetle attack (Table 4), except for the lowest dosage with the injector. On the average the actual amount of paraquat ion a tree received increased with increasing dosage. Thus it appears paraquat concentration, not quantity, is the key factor involved in bark beetle attack.

Table 4.--Bark beetle attack of paraquat treated loblolly pine by dosage, concentration, and wounding method.

| Paraquat Solution Dosage | Paraquat Concentration | Beetle Attack | |
|---|---|---|---|
| | | Tree Injector | Bark Streak |
| Ml/inch of wound | Percent | - Percent of trees involved - | |
| 0.15 | 0.5 | 0[a/] | 0 |
| 0.15 | 2.0 | 0 | 0 |
| 0.15 | 4.0 | 0 | 6.7 |
| 0.15 | 6.0 | 3.3 | 36.7 |
| 0.15 | 8.0 | 10.0 | 40.0 |
| | Average | 2.7 | 16.7 |
| 0.40 | 0.5 | 3.3 | 0 |
| 0.40 | 2.0 | 6.7 | 0 |
| 0.40 | 4.0 | 3.3 | 6.7 |
| 0.40 | 6.0 | 3.3 | 16.7 |
| 0.40 | 8.0 | 40.0 | 26.7 |
| | Average | 11.3 | 10.0 |
| 0.65 | 0.5 | 0 | 3.3 |
| 0.65 | 2.0 | 0 | 3.3 |
| 0.65 | 4.0 | 3.3 | 16.7 |
| 0.65 | 6.0 | 13.3 | 26.7 |
| 0.65 | 8.0 | 40.0 | 36.7 |
| | Average | 11.3 | 17.3 |

[a/] Each entry based on 30 trees.

## SUMMARY

1. There was no spread of bark beetle infestations from treated trees to adjacent untreated or less severely treated trees.

2. Very low mortality resulted when loblolly pine, treated with a 2 or 5 percent paraquat solution applied to a 1/3-circumference bark streak, was given minimal (0.1 percent BHC) or no insecticide spray.

3. Season of treatment had no effect on loblolly pine mortality when trees were given the paraquat treatments described above.

4. Injecting slash pine with 2 percent paraquat using a "Jim-Gem" caused a 10 percent loss in stand volume after 15 months, but the treatment should still be profitable.

5. Both beetle attack and tree mortality were positively correlated with the concentration of paraquat used.

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